5. IDENTIFICATION OF CHEMICAL EFFECTS THRESHOLDS

The purpose of this section is to quantify the concentrations of the 43 detected chemicals (Table 3-10) at which potential effects to aquatic life might occur. The end result of this section is development of a series of effect thresholds, against which measured concentrations can be compared. The effects thresholds represent chemical concentrations below which effects to aquatic life are not expected. Effects thresholds described here are based on published standards or criteria or, in the absence of such guidelines, on information in the scientific literature (i.e., AQUIRE database).

5.1. Sources

Screening thresholds were selected from three sources. These include: (1) Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC; (2) National Recommended Water Quality Criteria for Priority Toxic Pollutants (63 FR 68354-68364) plus any draft criteria; and (3) the AQUIRE (**AQU**atic toxicity **I**nformation **RE**trieval) database maintained by U.S. EPA.

5.1.1. WQS / WQC

Both Water Quality Standards (WQS) and Water Quality Criteria (WQC) were reviewed to identify and select effects thresholds[1]. Both acute (short-term) and chronic (long-term) criteria have been established for various metals and organic compounds in fresh and marine surface waters of the state (WAC173-201A). The acute standards are based on short-term toxicity tests evaluating lethal endpoints and reflect the highest surface water concentration to which aquatic life can be exposed for a brief period of time without causing unacceptable mortality levels. The chronic standards are based on longer-term sub-lethal toxicity tests with endpoints such as survival, growth, reproduction and development, and reflect the highest in-stream concentration of a toxicant to which aquatic life can be exposed indefinitely without causing an unacceptable effect (U.S. EPA 1991).

The U.S. EPA develops (Stephan et al. 1985) and publishes WQC based on protection of aquatic communities (including algae, invertebrates, and fish). Both draft and final WQC available to the public as of April 2001 were evaluated for use as effects thresholds for chemicals without an adopted State of Washington WQS.

[1] Water Quality Standards (WQS) are regulations adopted by individual states to protect aquatic life. Water Quality Criteria (WQC) are limits "believed to represent the best in scientific judgement at the time of their publication on concentration-effect relationships of a constituent that, when not exceeded, will protect aquatic life, the consumers of aquatic life, and the uses of water" (U.S. EPA 1979). States are required to use the WQC as the basis for developing standards when such criteria are available (although they are free to adopt more conservative values should they deem it appropriate).

5.1.2. AQUIRE

The AQUIRE database was established by the U.S. EPA in 1981, and contains information (e.g., toxicity data) on lethal and sublethal effect concentrations for aquatic organisms, including freshwater and marine plant and animal species. The majority of the toxicity data reported in this database was published between 1970 and the present. Priority is given to data published in peer-reviewed literature, but theses and dissertations, government reports and other "gray" literature are included as well. Lastly, computerized laboratory data files from the public sector and available unpublished reports have also been included and critiqued in the AQUIRE database.

For toxicity data obtained from the AQUIRE database, a minimum set of data quality requirements was established prior to using these data to develop screening thresholds for this report. These requirements were generally based on guidance established by U.S. EPA (Stephan et al. 1985). The AQUIRE database reports information that allows the user to evaluate the quality of the toxicity data. The following summarizes the key information categories reported by AQUIRE (termed fields) that were evaluated, and the types of information in each category (field) that were considered acceptable for the threshold identification process.

Exposure Duration – This field provides the period of time test organisms were exposed to a chemical or stressor. As such, exposure duration determines whether the toxicity test was acute (i.e., short-term) or chronic (i.e., long-term). Only data derived from tests that used exposure durations appropriate to the test species and type of toxicity test used were considered acceptable. For example, acute toxicity tests for most species are typically 96 hours in duration, but 48 hours is considered sufficient for some species and types of tests (e.g., bivalve larval development test and waterflea survival tests). Tests conducted over other short-term exposure durations (e.g., 24 hours) were used only if data from standard acute test durations (i.e., 48-96 hours) were not available. Ideally, chronic toxicity tests should encompass the life cycle of an organism through reproduction. This may be difficult to test in the laboratory for many organisms (particularly certain fish species, especially anadromous fish), so partial life cycle (e.g., juveniles through reproduction) or early life stage tests (embryo-larval life stages) were also considered acceptable.

Exposure Type – The screening thresholds identified through this process are only appropriate to evaluate direct water column exposure[2]. Toxicity tests based on nonrelevant exposure routes, such as injection, were not considered in this evaluation. Laboratory toxicity test exposure scenarios may be static, static-renewal, or flow-through. In static exposures, the exposure media (and associated chemical concentrations) is not renewed during the course of the test, while in static-renewal exposures, the exposure media (and associated chemical concentrations) are renewed at regular intervals over the duration of the test. In flow-through tests, chemical concentrations are continuously renewed. Preference was given to flow-through tests because organisms are likely exposed to a relatively constant chemical concentration. Acceptable acute tests could have been based on any of these exposure types, but it was necessary for chronic toxicity data to be based on static-renewal exposures or ideally flow-through exposure conditions to be acceptable.

[2] Dietary exposure was not evaluated through this process.

Chemical Analysis – Analytical verification of exposure concentrations in test solutions ensures test organisms are actually being exposed to the nominal concentrations and are not fluctuating significantly over the course of the test. It was not essential that exposure concentrations be verified for acute data to be acceptable, although these data would have been given preference over data derived from nominal concentrations. Given the relatively long duration of chronic toxicity tests, chemical concentrations should always be analytically verified for data from these tests to be acceptable.

Controls – Negative control organisms are reared in the same dilution water and conditions as test organisms, but are not exposed to stressors or chemicals being evaluated. The negative control ensures test organisms are healthy and that observed responses in treated organisms are due to particular test conditions (e.g., test chemical). Negative control responses should meet acceptability guidelines published by, for example, ASTM (1998). In AQUIRE, control responses are typically identified as "satisfactory," "unsatisfactory," or "indeterminate." For this evaluation, data were not used if controls were classified as "unsatisfactory." Data from tests with "indeterminate" controls were included in the screening process because a variety of tests report that controls were included, but do not necessarily discuss the control response if they were "satisfactory."

Dilution Water – The dilution water used in toxicity tests should not be of unusual origin or contain excessive concentrations of organic carbon or suspended matter that may reduce bioavailability of chemicals to test organisms. In addition, dilution water should have a pH, temperature, salinity, and dissolved oxygen level relevant to the organisms being tested. Again, ASTM (1998) has published test protocols on acceptable dilution water conditions. For this report, only results from tests conducted with freshwater were evaluated.

Endpoints – The endpoints considered for selection of acute data were primarily restricted to mortality, immobilization, and larval development. These endpoints are reported as either LC50 (median lethal concentration) or EC50 (median effect concentration) values in the AQUIRE database. For chronic test data, endpoints were based on mortality, reproduction, development, growth, or avoidance. These results are typically expressed as the no observed effects concentration (NOEC)[3] and lowest observed effects concentration (LOEC)[4].

Exposure Concentrations – It is preferable that exposure concentrations used in toxicity tests adequately bracket the acute LC/EC50 or chronic threshold (i.e., the NOEC and LOEC). If only a chronic NOEC or LOEC was available for a chemical, the data were used to identify a screening threshold, but results of any comparisons with measured contaminant concentrations should be interpreted cautiously. For example, if a measured contaminant concentration were less than an NOEC-based effect threshold, then an effect would not be predicted. However, if the measured contaminant concentration were greater than the corresponding NOEC-based effect threshold, it would be unknown if the contaminant would be of concern. Conversely, while an LOEC by itself would be useful

[3] The NOEC is the highest test concentration that did not result in statistically significant effects when compared to the control.

[4] The LOEC is the lowest test concentration that resulted in statistically significant effects when compared to the control.

for confirming a contaminant were present at a high enough concentration to be of concern; it would be uncertain whether a concentration less than the LOEC would be of concern.

Species – Only data from freshwater environments were evaluated for selection of thresholds.

The above discussion summarizes the factors that influenced whether data obtained from the AQUIRE database were considered acceptable for developing effects thresholds for this study. The lowest acceptable AQUIRE toxicity test threshold found in the database search was selected as the effects threshold.

5.2. Standards / Criteria / Thresholds

5.2.1. Pesticides

Of the 26 pesticides detected, standards or criteria were available for four compounds (Table 4-1). For this analysis, the lowest (i.e., chronic, when available) freshwater standard or criteria was selected for evaluating which chemicals potentially may be impacting aquatic life and therefore warrant a more detailed investigation.

Table 4-1. Effects thresholds for aquatic life based upon standards and/or criteria (µg/L) for detected pesticides.

Parameter	Standard	Criterion
Diazinon	N/A	0.09
Malathion	N/A	0.1
Pentachlorophenol	9.5[b]	N/A

[a] The lowest value (i.e., chronic, when available) was selected for this screening-level evaluation.

[b] The standard for pentachlorophenol is pH dependent; the value reported here is based upon a pH of 7.5.

For detected pesticides without standards or criteria, the AQUIRE database was searched and the lowest acceptable freshwater value was selected as the effects threshold (Table 4-2). The lowest acceptable value was generally based on a chronic study; however, for some compounds there were few toxicity data available and the lowest value may have been based on acute toxicity. Acute-to-chronic toxicity ratios (ACRs) were not applied to these acute data as ACRs were generally not available. In addition, ACRs tend to be compound specific and vary depending on the sensitivity of the species tested (Stephen et al. 1985, Brix et al. 2001). For the studies selected to develop effects thresholds, details from the AQUIRE database (e.g., species, test duration, pH, etc.) are provided in Appendix D. For one compound, desethylatrazine, no acceptable data were obtained from the AQUIRE database.

Table 4-2. Effects thresholds (µg/L) identified from the AQUIRE database for detected pesticides lacking water quality standards or criteria.

Parameter	Effect Threshold (µg/L)	Test Design
2,4-D	30	Chronic
2,6-Dichlorobenzamide	13,416	Chronic
4-Nitrophenol	989	Chronic
4,4'-DDT [a]	0.035	Acute
4,4'-DDE	0.83	Acute
4,4'-DDD	0.09	Acute
Atrazine	3.4	Chronic
Bromacil	10	Chronic
Carbaryl	3.33	Acute
Dicamba	30.5	Chronic
Dichlobenil	3,100	Acute
Dichlorprop	1,350	Acute
MCPA	1,400	Acute
MCPP	2,573.5	Chronic
Metolachlor	5	Chronic
Napropamide	1,700	Chronic
Prometon	49	Chronic
Simazine	0.307	Chronic
Trichlorpyr	150	Acute
Trifluralin	3.154	Chronic

[a] The chronic standard for DDT (0.001 µg/L) was established to be protective of human health from consumption of aquatic organisms. Therefore, this value was not selected in favor of the lowest acceptable value identified in the AQUIRE database search.

5.2.2. Metals

Measurement of total recoverable metal (TRM) concentrations includes some fraction of the metal that is bound to suspended solids or is strongly complexed with organic matter or other ligands and therefore is not available to bind to gill receptor sites. Therefore, standards for most metals are based on the dissolved fraction of the metal, as opposed to the TRM, as it more closely approximates the metal's bioavailable[5] fraction, and thus, toxicity (Prothro 1993, U.S. EPA 1993). On the other hand, metals bound to suspended solids may settle and contribute to sediment metal loads. These sediment-associated metals may be incidentally ingested by water column organisms or be accumulated by benthic organisms and thus enter into the food chain. However, mechanisms of chronic

[5] Bioavailability is the degree to which a contaminant in a potential source is free for uptake (movement into or onto an organism) (Hamelink et al. 1994).

toxicity from dietary exposure are not well understood; therefore, they are beyond the scope of this analysis.

The effects thresholds based upon water quality standards and criteria for metals are listed in Table 4-3. As noted in the table, a number of freshwater metal standards are dependent on the hardness of the receiving water. The water hardness affects the bioavailable fraction of the metal. As the hardness increases, the metal is less bioavailable, and therefore, less toxic. For hardness dependent metals, a hardness of 50 mg/L $CaCO_3$ was assumed for presentation in Table 4-3. However, when comparing measured concentrations with effects thresholds (Section 5), site-specific hardness measurements calculated from the total calcium and magnesium concentrations were used to adjust hardness-dependent effects thresholds.

For detected metals without standards or criteria, the AQUIRE database was searched and the lowest acceptable freshwater value was selected as the effects threshold. These thresholds are listed in Table 4-4. For the studies selected to develop effects thresholds, details from the AQUIRE database (e.g., species, test duration, pH, etc.) are provided in Appendix D.

Table 4-3. Effects thresholds based on available water quality standards or criteria for detected metals (µg/L).

Parameter	Standard[a]	Criterion[a]
Aluminum, total	N/A	87
Antimony (III), acid-soluble	N/A	30
Arsenic, dissolved	190	N/A
Beryllium, total	N/A	5.3
Cadmium, dissolved[b]	0.6	N/A
Chromium (VI), dissolved	10	N/A
Chromium (III), total[b]	100.9	N/A
Copper, dissolved[b]	6.3	N/A
Lead, dissolved[b]	1.2	N/A
Nickel, dissolved[b]	87.4	N/A
Zinc, dissolved[b]	58.1	N/A

[a] The lowest value (i.e., chronic) was selected as an effects threshold.

[b] Criteria hardness dependent. Value shown based on 50 mg/L $CaCO_3$.

Table 4-4. Effects thresholds (µg/L) identified from the AQUIRE database for detected metals lacking water quality standards or criteria.

Parameter	Effects Threshold	Test Design
Barium, total	4,450	Chronic
Cobalt, total	5.1	Chronic
Molybdenum, total	880	Chronic
Vanadium, total	80	Chronic

5.2.3. BNA Organics

Of the three BNA organics detected, a criterion was only available for only bis(2-ethylhexyl)phthalate (Table 4-5). Effects thresholds were selected from the AQUIRE database for the other two detected organics, benzoic acid and caffeine (Table 4-5).

Table 4-5. Effects thresholds (µg/L) for detected BNA organics.

Parameter	Screening Threshold
Criteria- based	
bis(2-ethylhexylphthalate)	360
AQUIRE-based (acute)	
Benzoic acid	112,500
Caffeine	20,000